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IMAGE SEQUENCE ENHANCEMENTS BASED ON
THE NORMAL COMPONENT OF IMAGE MOTION

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ABSTRACT

Huang and Hsu [1] describe an image sequence enhancement algorithm based on computing motion vectors between successive frames and using these vectors to determine the correspondence between pixels for frame averaging. In this note, we demonstrate that it may be sufficient to use only the components of the motion vectors in the gradient direction (called the normal components) to perform the enhancement.

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intensity, then it is sufficient to simply determine a correspondence between nearby points that belong to the same image region, since their intensities should be quite similar. The normal component can be used to establish such a correspondence. Indeed, let P be a pixel, let P^* be the result of displacing P by the true motion vector, and let P' be the result of displacing it by the normal component only. Thus P^* is the true position of P under the motion; but P' differs from P^* only by the (unknown) tangential component of the motion, and so is likely to belong to the same region as P^* . The concept here is analogous to that used in early work on smoothing of single images [2], where a pixel at which the gradient magnitude is high is smoothed by averaging with its neighbors in the tangential direction only.

2. Enhancement algorithm

Let f_1 and f_2 be two frames from a motion sequence, and let m be the field of normal components of the motion vectors between f_1 and f_2 . The picture m is a vector-valued picture, where $m(x,y) = (u,v)$; u is the projection of the normal component on the x -axis and v is the projection of the normal component on the y -axis. We will let $u(x,y)$ and $v(x,y)$ denote the u and v components of m at (x,y) .

We compute an enhanced version of f_2 , which we will denote as g_2 , by the following two stage process:

1) Create a "shifted" version of f_1 , denoted f'_1 , as follows:

a) Initially, for all (x,y) set $f'_1(x,y) = U$ (for "undefined")

b) For all (x,y) set $f'_1(x+u(x,y), y+v(x,y)) = f_1(x,y)$

2) Create the enhanced version of f_2 as follows:

For all (x,y)

If $f'_1(x,y) = U$ Then $g_2(x,y) = f_2(x,y)$

Else $g_2(x,y) = [f'_1(x,y) + f_2(x,y)]/2$

In step (1) the pixels having no predecessor in the image under the motion are assigned the value "U" in the shifted version of f_1 . At these positions we cannot compute a correspondence between pixels in f_1 and f_2 , so that we use the intensities in f_2 to form the enhanced image. Also, it is quite possible that several points in f_1 map onto the same point in f'_1 due to errors in the normal components. Note that this could also happen if we used the motion vectors rather than only the normal components.

The above algorithm can be simply extended to compute enhancements based on sequences of more than two frames. Let f_1, f_2, \dots, f_n be the sequence of frames for which we wish to produce an enhanced image. We proceed as follows: Let m_i be the normal component or motion vector field for the i th frame. Apply the above algorithm to frames f_1 and f_2 to produce an enhanced image of those two frames, which we will denote by g_{12} . Next, apply the enhancement algorithm to g_{12} and f_3 (using the motion vector field m_2 computed from the initial sequence) to produce an enhanced version of f_1 - f_3 denoted g_{13} . Continuing in this manner, we can produce an enhanced version of frames f_1 to f_n .

A problem with this approach is that as we compose the motion vector fields in moving through the sequence the errors in the individual motion vector fields accumulate, so that g_{in} is not a uniformly good enhancement of f_1 to f_n . Instead we adopted the following "triangular" procedure which takes advantage of the intermediate computations that would have to be done to compute enhancements of subsequent sequences (e.g., f_2 to f_{n+1}) for computing the enhancement of f_1 to f_n . Instead of simply regarding g_{in} as the enhanced version of f_1 to f_n , we compute the median of g_{in} , $i=1, n-1$ and f_n as the enhancement. The images g_{in} , $i=2, n-1$, are intermediate results in the computation of $g_{i, i+n-1}$ and so must be computed in any event. We found experimentally that median filtering results in better enhancements than simple averaging.

3. Experimental results

Figures 1 and 2 show two image sequences, each containing 8 frames. Sequence 1 contains images of a printed page which was moved in front of the camera parallel to the image plane (thus the motion was a two-dimensional motion). White noise was then added to each frame in the sequence. Sequence 2 contains images of a toy with significant detail. The camera was rotated so that the image of the toy moved from left to right in the sequence, and in this case the motion is a three-dimensional motion.

The results comparing enhancements obtained using the normal components of the motion vectors versus the actual motion vectors are displayed in Figures 3 and 4. The motion vectors and normal components were computed using a differential technique. Spatial and temporal intensity derivatives were approximated based on cubic spatial and temporal approximations to sequences of five frames, with the motion vectors associated with the third frame in each sequence of five. The motion vectors were derived from the normal components under the assumption that the motion was locally a simple image plane translation (see, for example [3,4, 5]). For comparison, enhancements based on both averaging and median filtering (see the discussion at the end of the previous section) are displayed, as well as enhancements without motion compensation. The results using the motion vectors and the normal components are quite comparable, and indicate that it may not always be necessary to incur the additional expense of determining the true motion vectors to perform enhancement.

4. Conclusions

In this paper we have demonstrated that it may not always be necessary to compute motion vectors to enhance image sequences, and that instead it may be sufficient to consider only the normal component of motion. However, we should note that this observation may depend on the specific enhancement algorithm chosen; also, since the evaluation of image enhancements is based on visual, subjective criteria we should point out that Huang [1] remarked that the enhancements are stronger when the enhanced images are themselves viewed as an image sequence. We were unable to perform such a "dynamic" comparison with normal component enhancements, but the results of such a subjective comparison would be important in deciding whether or not to use just the normal components for enhancement .

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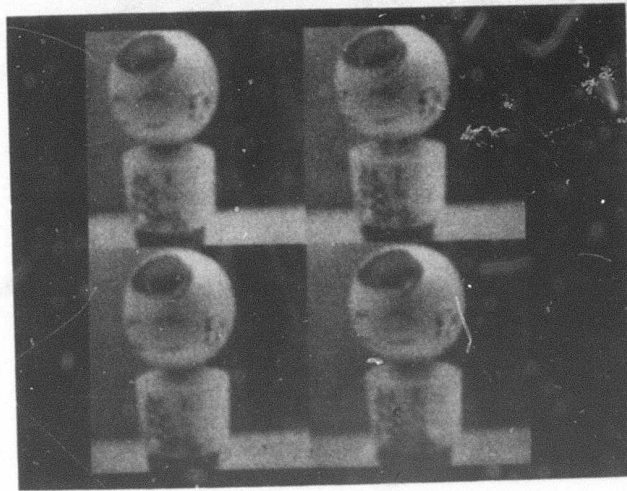
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Figure 1. Two-dimensional motion sequence.

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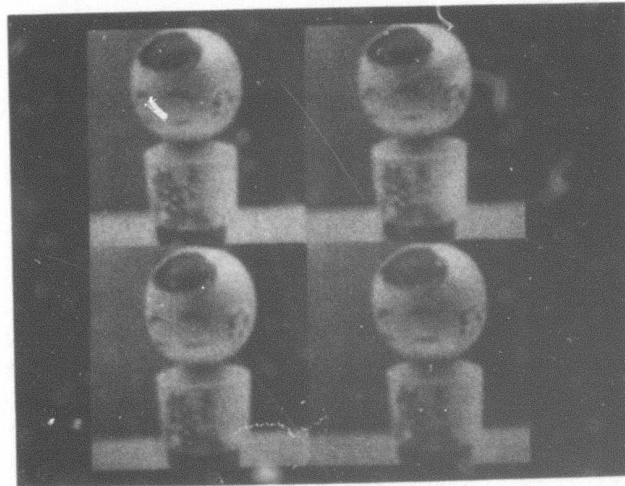


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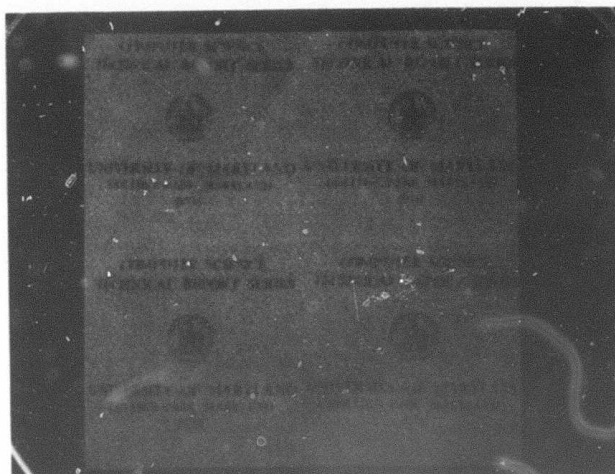


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Figure 2. Three dimensional motion sequence.

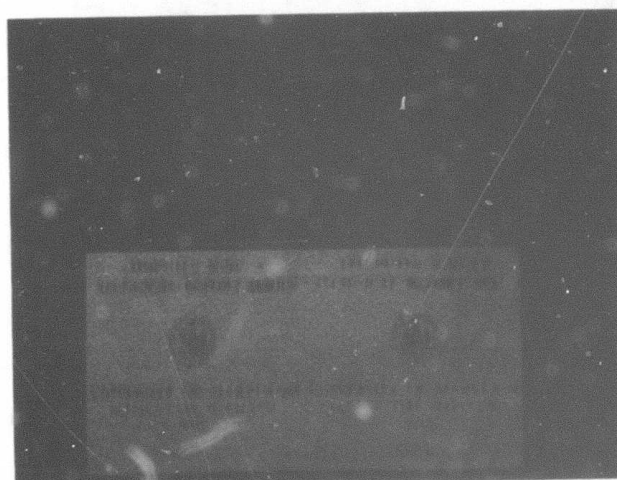


Normal component

Motion vector

Mean

Median

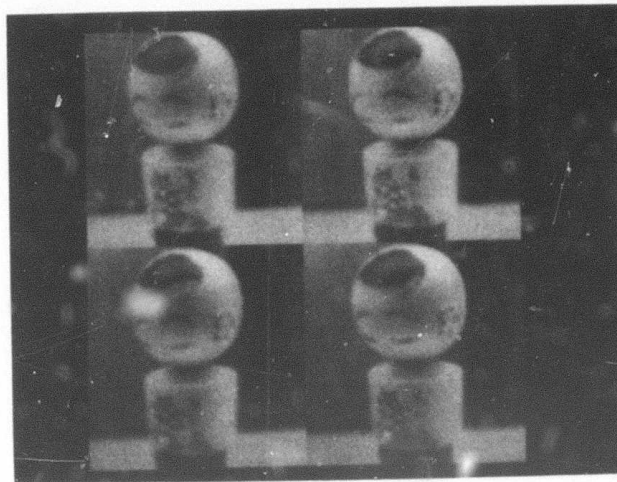


No motion
compensation

Mean

Median

Figure 3. Enhancements of Figure 1.

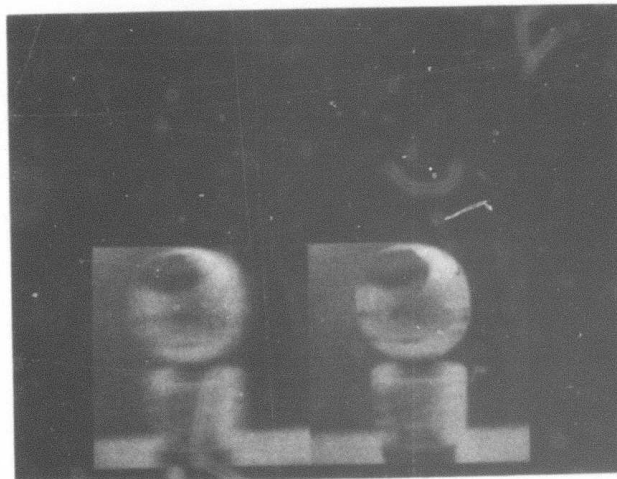


Normal component

Motion vector

Mean

Median



No motion
compensation

Mean

Median

Figure 4. Enhancements of Figure 2.

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